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Evaporation Memorandum No.24.

Data for the investigation of climatic trends influencing the rate of evaporation and of the frequencies with which various average rates of evaporation are sustained over periods of one calendar month or more.

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Summary. It is shown that useful approximations to monthly estimates of potential evaporation made using Penman's formula (with temperature, humidity, sunshine and wind data) can be obtained, for a given station, from values of monthly average (screen) air temperature and long-average values of monthly wind speed at 2 metres above ground and of daily duration of bright sunshine.

Introduction.

Estimates of (Penman) potential evaporation can readily be prepared for stations and periods for which values of the four required meteorological variables are available. For the investigation of the possible effects of climatic trends on evaporation and for frequency work it is desirable to obtain sets of consecutive monthly estimates of evaporation covering at least two hundred years. Measurements and estimates of average monthly air temperature are available from the early 18th. century onwards for the London area but measurements of humidity, duration of bright sunshine and wind speed have only been made, regularly, during the last hundred years or less.

1. Sunshine and Temperature.

Monthly averages of screen air temperature and of daily duration of bright sunshine for Kew Observatory for the period 1921-40 are compared in Figures 1 (a) to (l). Plausible curves have been drawn through the monthly sets of points.

After the cuvres had been drawn the 1931-60 averages of screen temperature and daily duration of bright sunshine were plotted against one another. These points (X) lie below the curves from December to February but on the curves in the other months. For interest, the monthly absolute maximum temperatures are plotted against maximum possible duration of bright sunshine - although these two variables are not directly related. These points are shown as circled crosses.

The known relationship between sunshine and temperature is shown up but there is a wide scatter of sunshine duration about any given average temperature-based estimate of sunshine. This is in accordance with experience.

Three methods were used to estimate monthly values of average daily duration of bright sunshine at Kew for the decade 1961-70.

(a) estimates were obtained from the curves of Fig.1 on the basis of actual average temperature,

(b) the 1931-1960 monthly averages of daily duration of bright sunshine were used as estimates of actual month averages,

(c) the 1931-60 averages were used from November to February and the "temperature-derived" estimates were meaned with corresponding 1931-60 averages for the other months.

The distributions of errors in using these three methods is shown in Table 1. The 1931-60 averages give fewer large errors than the temperature-derived estimates. The "combined" method (c) compares well with (b) and has the advantage, from the physical point of view, of using the best estimates in the months of low solar radiation intensity and taking account of the radiation - temperature relationship in the warmer months.

2. Vapour pressure and Temperature.

Monthly averages of screen air temperature and of vapour pressure (computed from daily mean temperature and daily mean relative humidity) for Kew, for 1921-40 are compared in Figures 2 (a) to (l). Plausible regression lines have been inserted by eye; the month-to-month trend of the slope being used as an aid in positioning the lines for summer months.

Using monthly average temperatures at Kew for the decades 1941-50 and 1961-70, estimates of vapour pressure were read from Figures 2 The two sets of estimates are compared with the corresponding averages of observed values in Figures 3 (a) and (b). Approximate regression lines have been inserted by eye. For 1941-50 (Fig.3(b)) the 1:1 line is acceptable but the line for 1961-70 (Fig.3(a)) shows that the estimates are some 5% higher than the averages of measurements.

From 1957 onwards, summaries of meteorological observations were no longer printed in the Observatories' Year Books and the monthly averages of vapour pressure were obtained from hourly averages for 09, 15 and 21 hours GMT, conveniently available in the Monthly Weather Report. Comparisons of these two methods of obtaining monthly averages of vapour pressure, for two years chosen at random, are as follows:-

	Kew Observatory.	Monthly Averages of Vapour pressure											
Year.	Method.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1950	1/3(09 15 21)	7.2	8.2	8.2	7.8	10.4	14.1	14.8	14.7	12.8	10.4	8.5	5.9
	Mean TT and RH	7.6	8.3	8.3	8.0	10.4	14.4	15.0	14.8	13.0	10.6	8.7	6.0
1956	1/3(09 15 21)	7.2	4.7	7.2	7.0	9.8	11.7	14.7	13.3	14.7	10.4	8.0	8.9
	Mean TT and RH	7.3	4.8	7.4	7.2	10.1	11.8	14.9	13.4	14.7	10.6	8.2	9.0

Yearly averages of monthly values are -

1950	10.250 10.425	error 1.7 %	and	1956	9.950 9.800	error 1.5 %

thus the mean error is 1.6 % In every case the average of the three hourly averages is either the same or less than that obtained from temperatures and humidities at all hours. Thus the method of estimating vapour pressure from temperature, which was based on vapour pressures obtained from hourly temperatures and relative humidity values, over-estimates the value obtained from the three chosen hours but never under-estimates it (on the basis of a two-year sample).

3. Wind Speed.

Daily run-of-wind measurements at 2 metres above ground are available from Kew, for whole years, as from January 1957. Table 2 is a frequency table of average daily run on a monthly basis, for the 14-year period 1957-70. The average daily run for each month is given at the right-hand side of the table, followed by the difference, in knots, between the average and extreme runs, each month, expressed as run/24, i.e. average speed. If the long-average mean speeds had been used as estimates of the actual monthly average speeds the greatest error involved would have been 1.9 knots in February and in the months with relatively large evaporation values, March to October, the greatest error would have been only 1.6 knots.

4 Penman Potential Evaporation.

The next step was to obtain, by computer, monthly estimates of totals of potential evaporation (for albedo 0.25) for Kew for the decade 1961-70, (a) using real averages of air temperature, vapour pressure, duration of bright sunshine and wind run at 2 m. and, (b) using the same averages of air temperature, estimates of vapour pressure and duration of bright sunshine and monthly average (1957-70) wind speeds.
The P.E. estimates obtained by the two methods (but the same formula) are set out in Tables 3 and 4, together with monthly averages and annual totals.

The two decadal sets of estimates are compared in Figure 4, from which it is seen that only three of the estimates obtained with restricted data differed from the corresponding estimates based on full data by more than 1/2 inch.

Examination of Tables 3 and 4 shows that estimates obtained with restricted data (referred to in future as "modified P E " or PE') are generally (but not always) lower than those based on full data.

It has been shown, already, that vapour pressures estimated from temperatures are higher than the averages of real vapour pressures as calculated for this decade. The explanation of an average difference of some 1.6% has been given but the whole average difference was some 5 %. In view of the approximations involved in this work the small discrepancy has not been examined. As will be seen in a later section, allowance has be made for the whole 5%.

5. Potential Evaporation, Modified Potential Evaporation and Temperature.

Thus, for Kew, monthly estimates of PE (called PE') can nearly always be obtained to within 1/2 inch of the PE estimates based on full data, using only monthly average temperature and monthly averages of sunshine duration and of run-of-wind at 2 metres (above ground). The relationships between temperature and sunshine and between temperature and vapour pressure vary significantly and systematically from month to month. Useful estimates are, therefore, available from minimal data and accuracy is improved when more than the minimum of data are available.

In Figures 5 (a) to (l) monthly average temperature is plotted against Modified PE (PE') from Table 4. The lines have been inserted by eye and those for the four cold months are, clearly, not entirely satisfactory. They do, however, enable reasonable estimates of PE' to be obtained easily.

6. Tables for obtaining PE' without calculation.

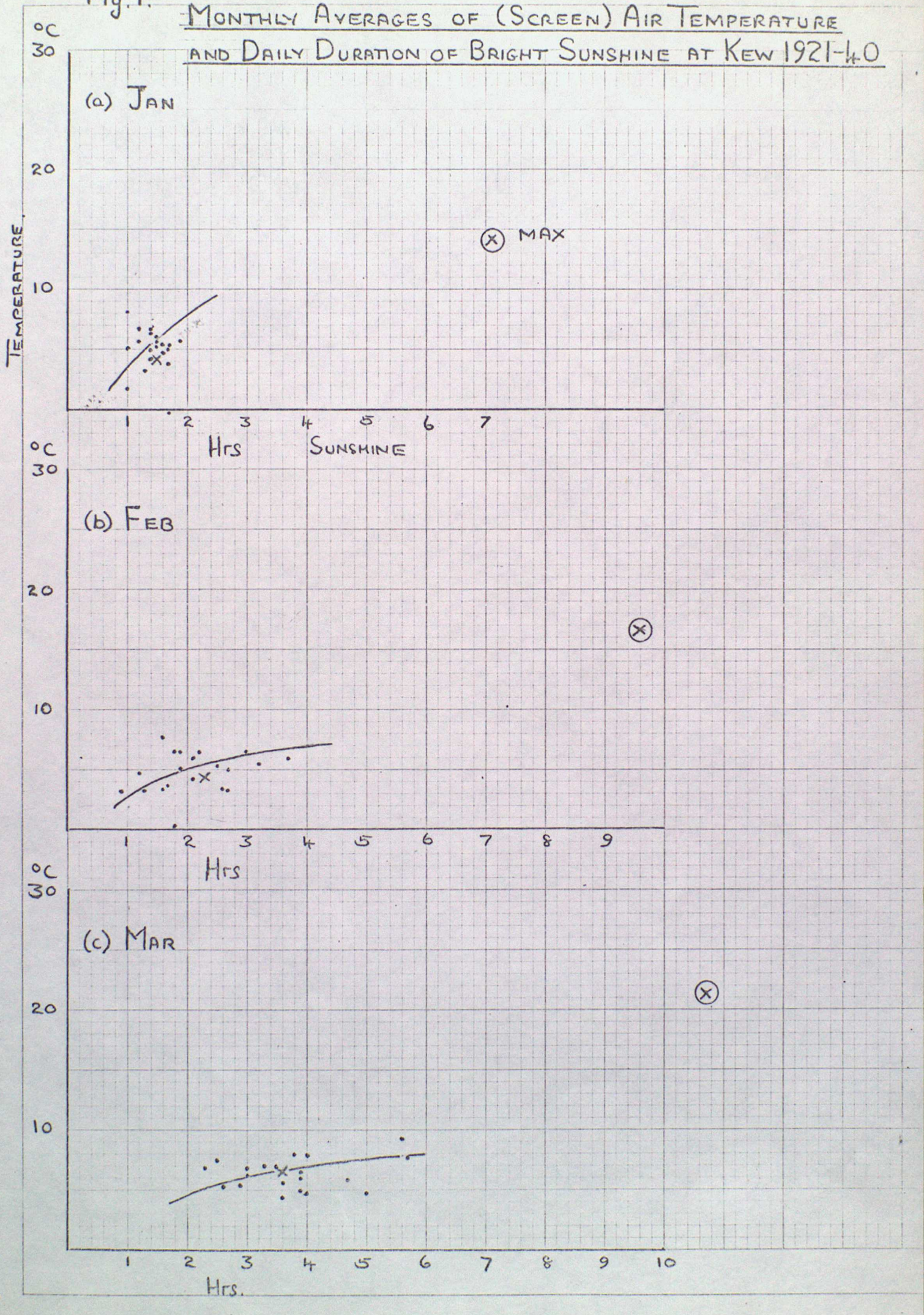
Table 6 presents the relationships shown in Figures 5. but with slight modifications. The vapour pressure discrepancy effect in 1961-70 is allowed for, since the Figure 5 relationships were obtained in this period. The monthly estimates and averages of estimates in Table 4 (PE') have been divided by the corresponding values in Table 3 (PE) and the results have been multiplied by 1.025 to increase all PE' estimates by 2.5 %. This adjustment, derived from a table in "Meteorological Data and the Agricultural Problem" by P.E. Waggoner (Reading Symposium Proceedings 1966), is considered reasonable and of sufficient accuracy for the present purpose. The values in Table 5 are PE'/PE for 1961-70. The table was inspected and where the individual monthly values were predominantly less than or greater than unity the value 1/Average was calculated as a factor to modify all estimates of PE' obtained by the "temperature method". In practice the values in consistent months were less than unity. The factor was applied to Figure 5 values for November to February before tabulation

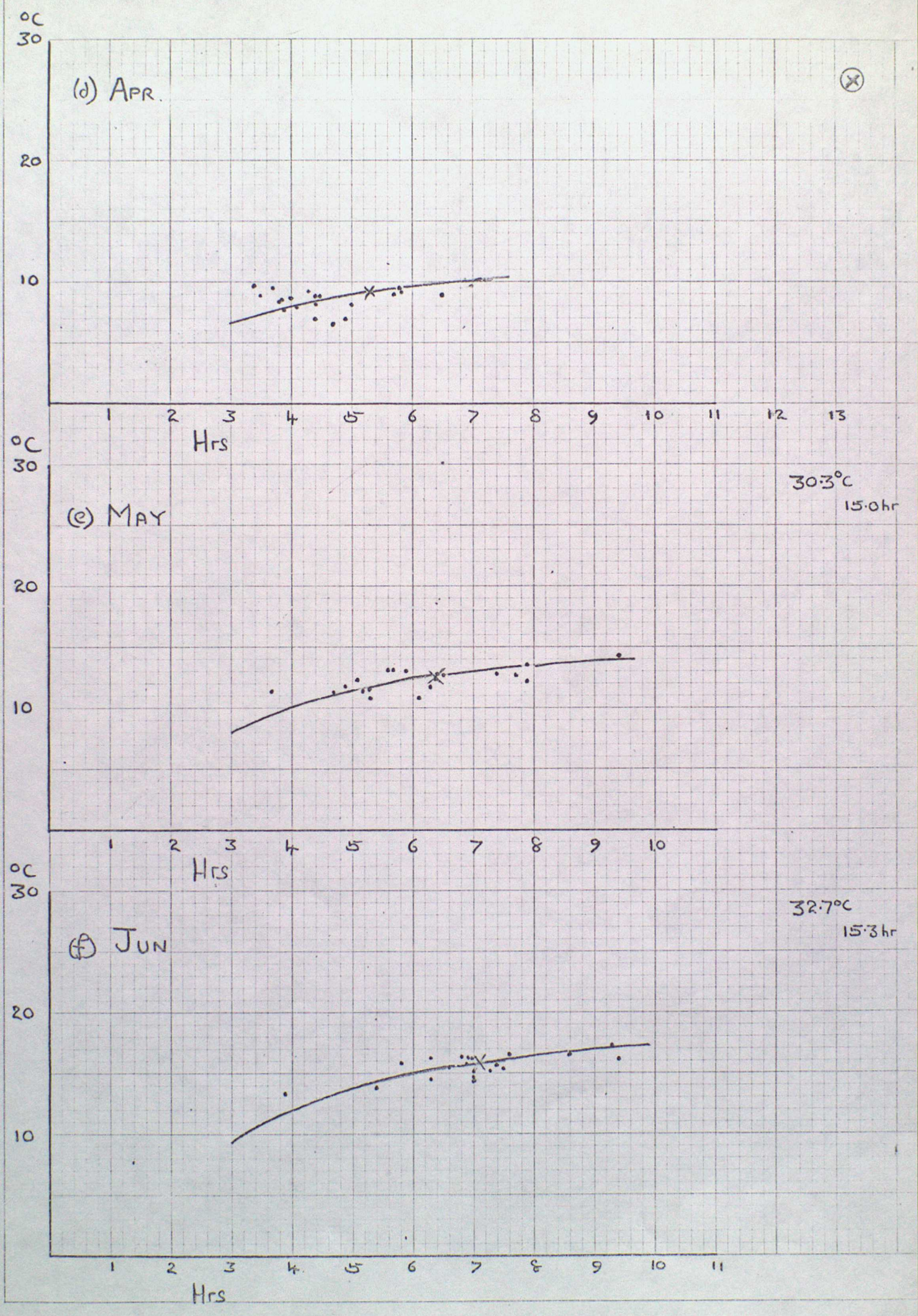
Conclusion. The results could have been obtained, in part, from a direct, simple regression of PE on temperature for Kew but this method would not have provided the means of making use of fragmentary data and of sets of data lacking one, two or three of the meteorological variables (other than temperature) in a reasonably coherent series of estimates of (Penman) PE.

Bracknell. December 1972.

Fig. 1.

Monthly Averages of (Screen) Air Temperature and Daily Duration of Bright Sunshine at Kew 1921-40




°C
30
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(d) APR.
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Hrs
°C
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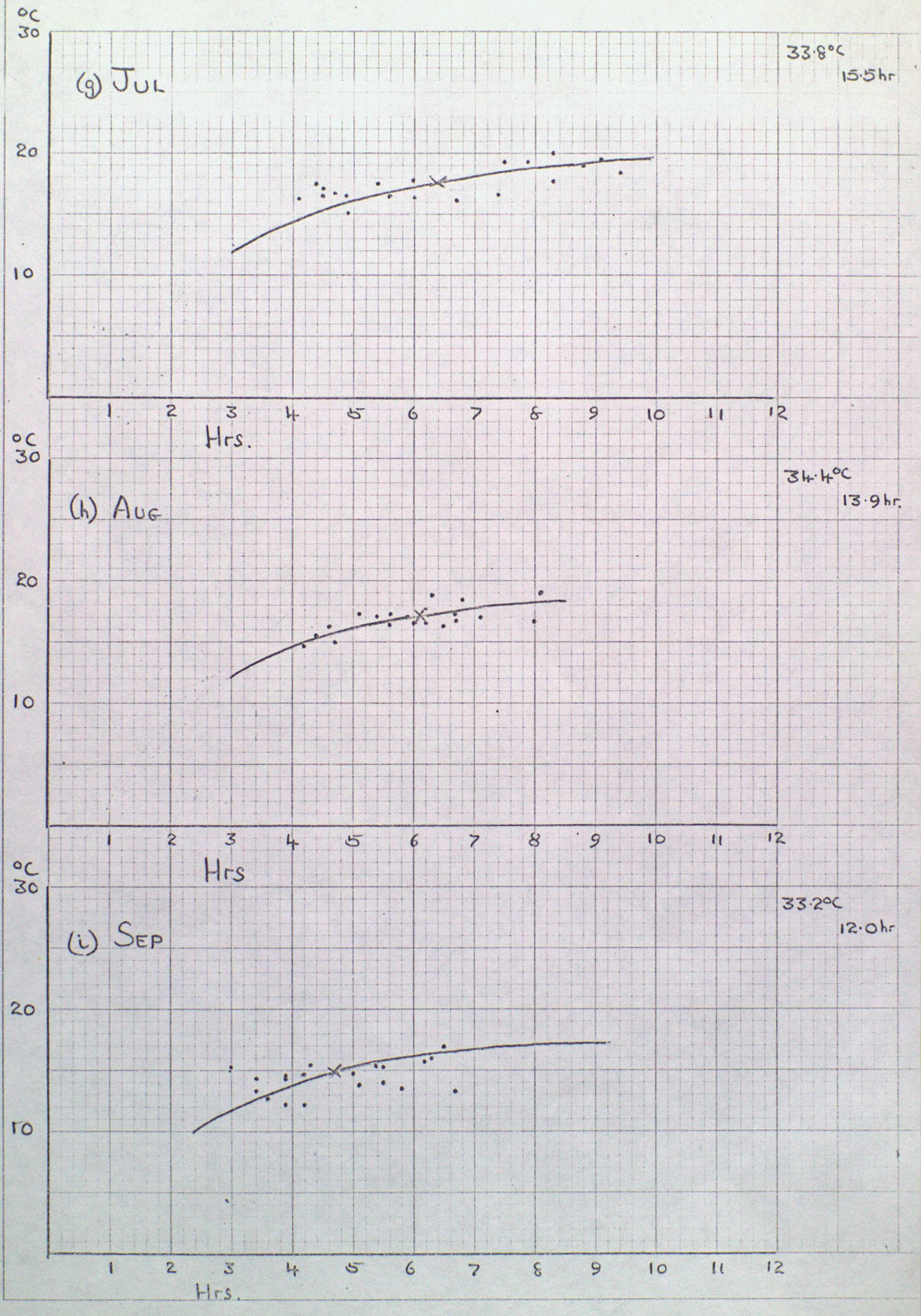
(e) MAY
30·3°C
15·0hr
1 2 3 4 5 6 7 8 9 10
Hrs
°C
30
20
10
(f) JUN
32·7°C
15·3hr
1 2 3 4 5 6 7 8 9 10 11
Hrs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(h) AUG
34·4°C
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1 2 3 4 5 6 7 8 9 10 11 12
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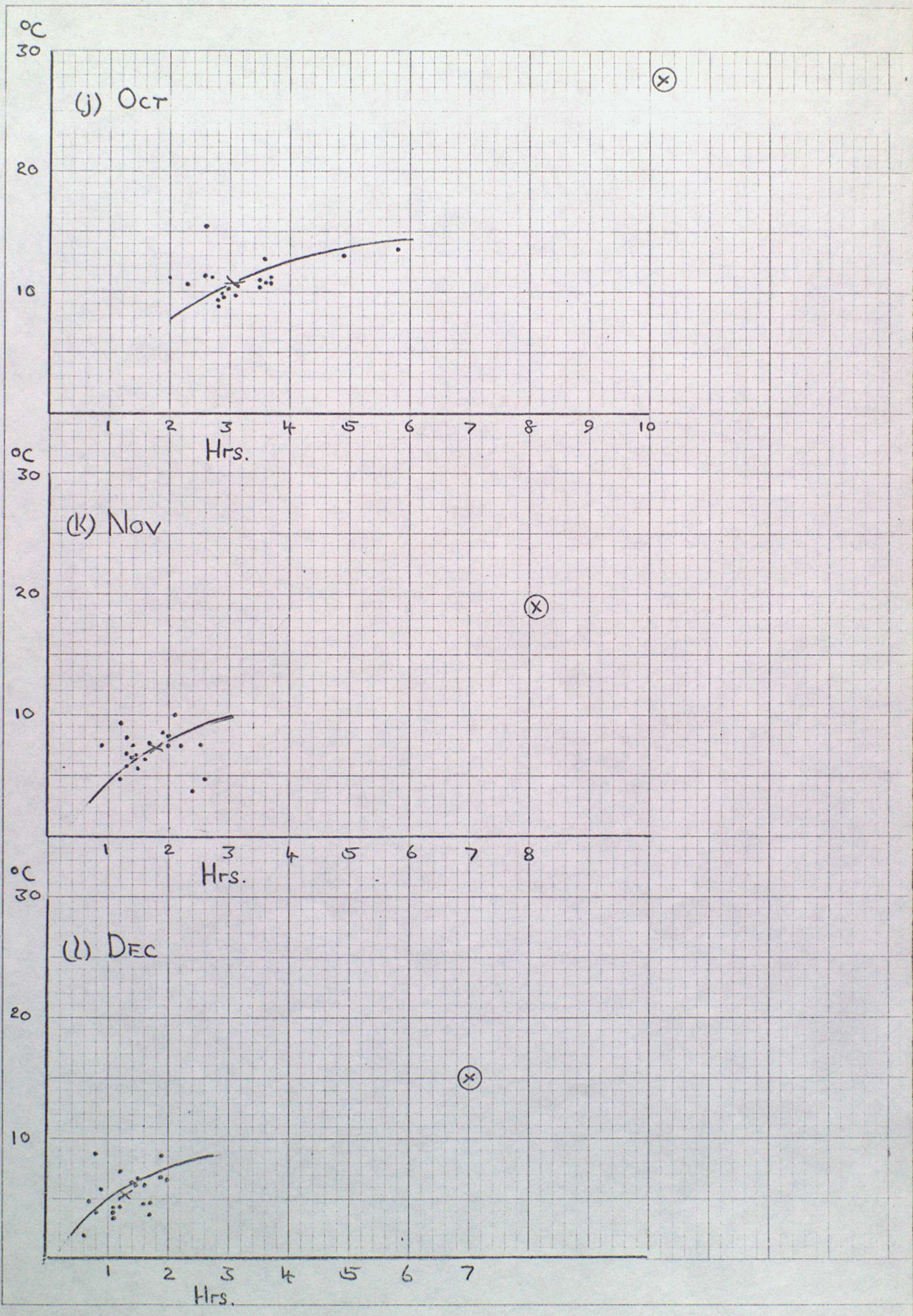
°C
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Fig.2 KEW 1921-1940

MONTHLY AVERAGE AIR TEMPERATURE AND VAPOUR PRESSURE.

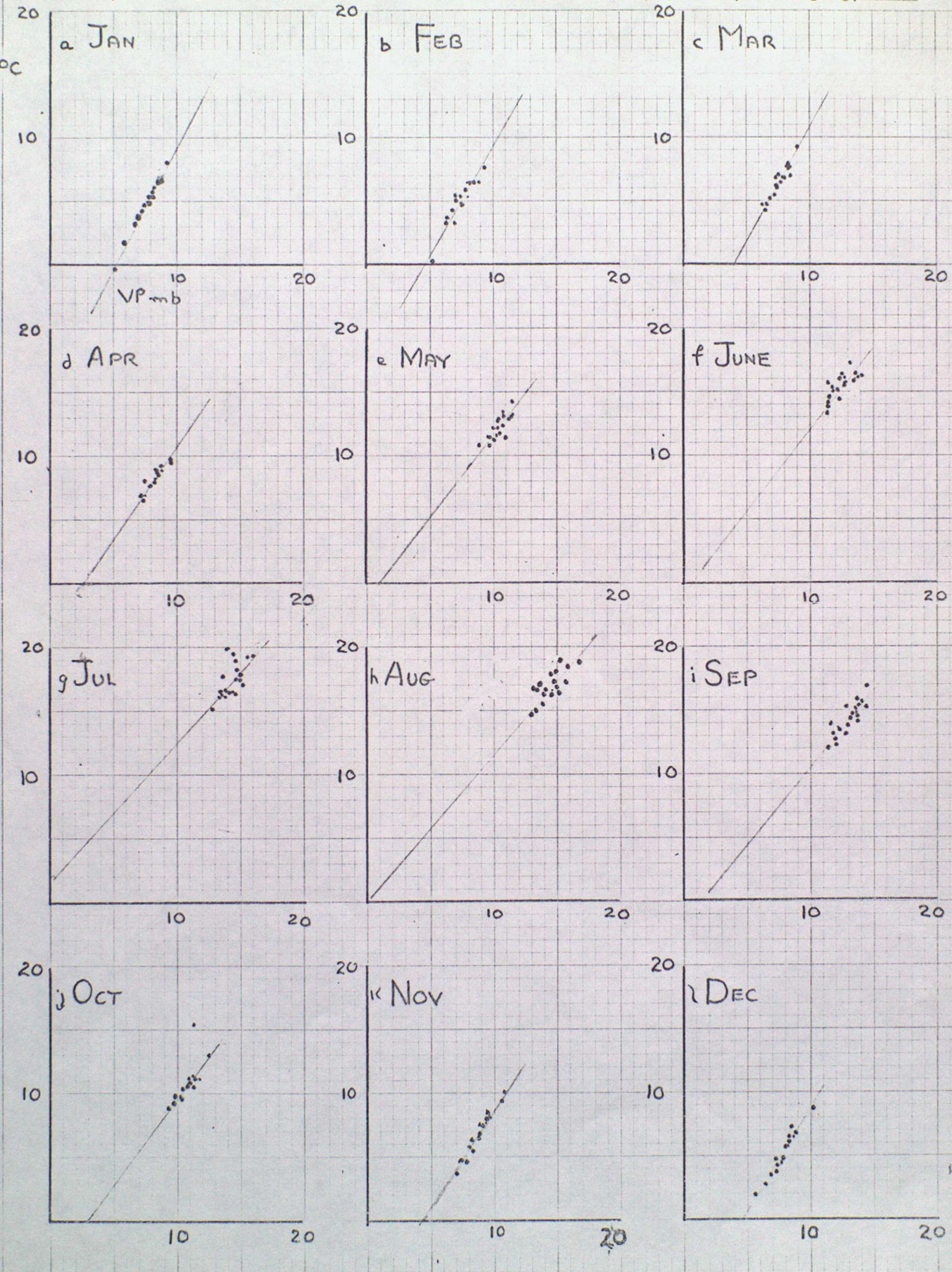


Fig 3(a) KEW 1961-1970

ERRORS IN ESTIMATING MONTHLY AVERAGE VAPOUR PRESSURE FROM AVERAGE (SCREEN) TEMPERATURE.

AVERAGES MARKED X WERE OBTAINED FROM ASPIRATED INSTRUMENTS IN THE "GARDEN" SCREEN.

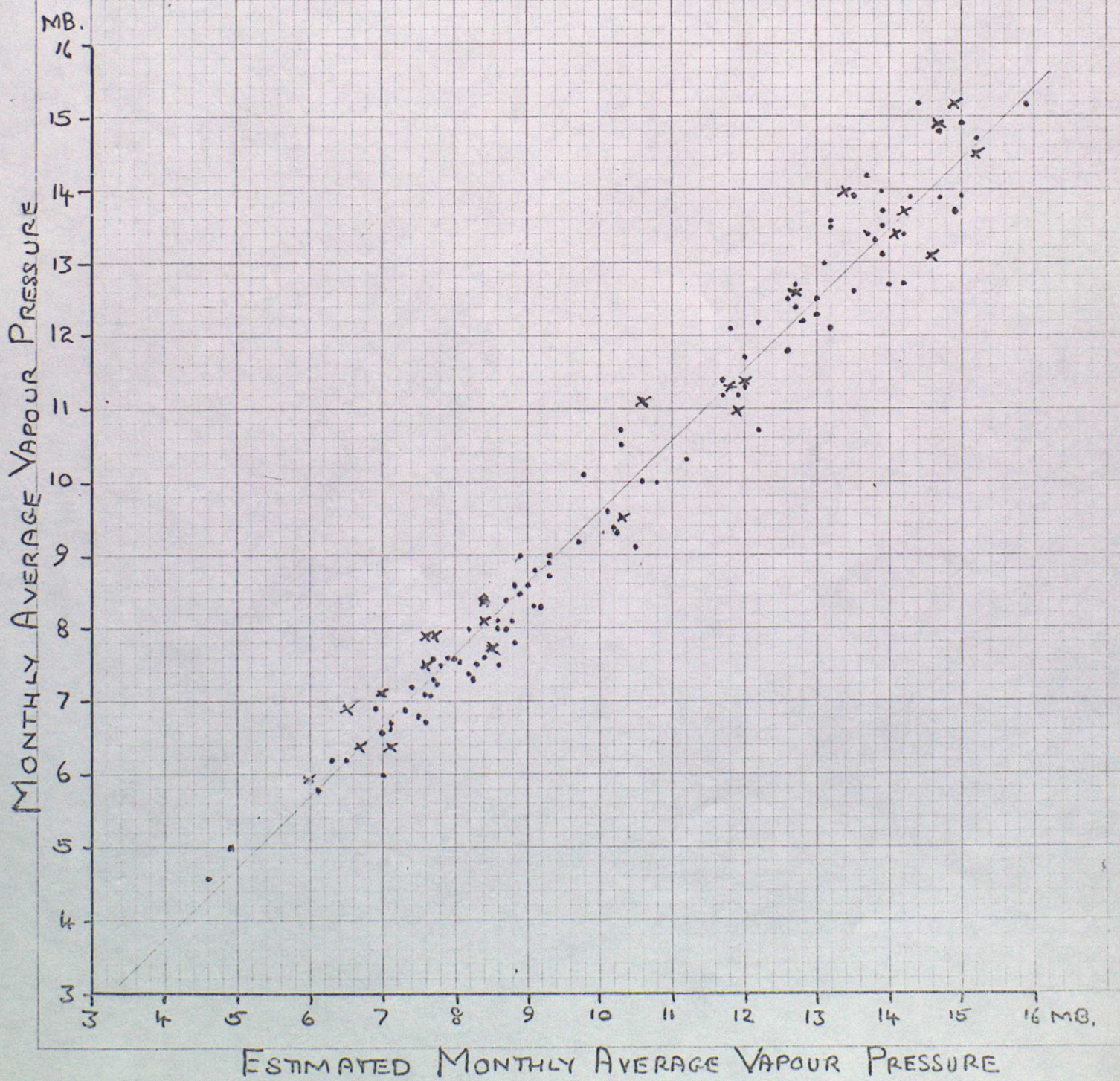


Fig. 3 (b) KEW 1941-50

ERRORS IN ESTIMATING MONTHLY AVERAGE VAPOUR PRESSURE FROM AVERAGE (SCREEN) TEMPERATURE.

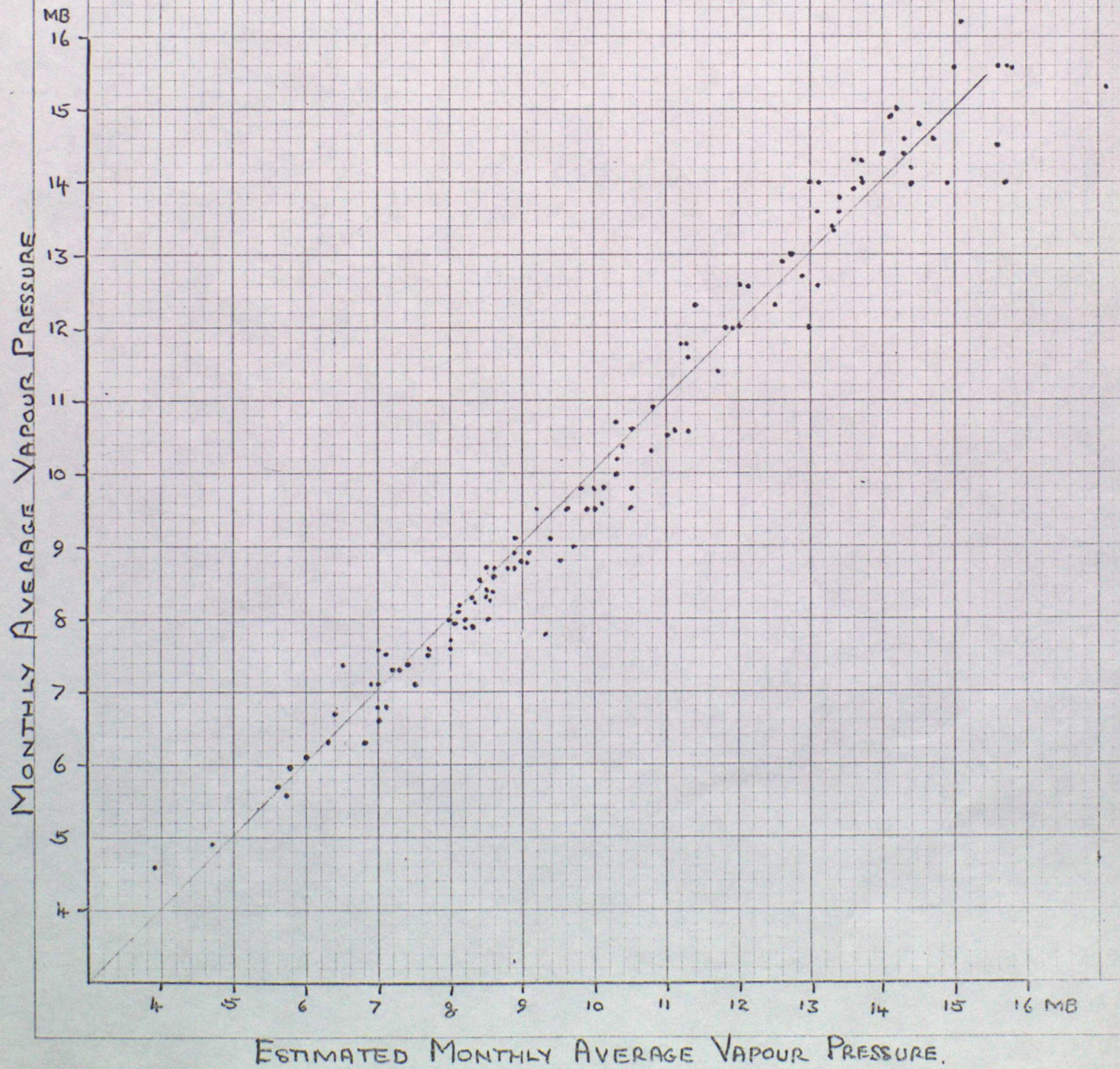
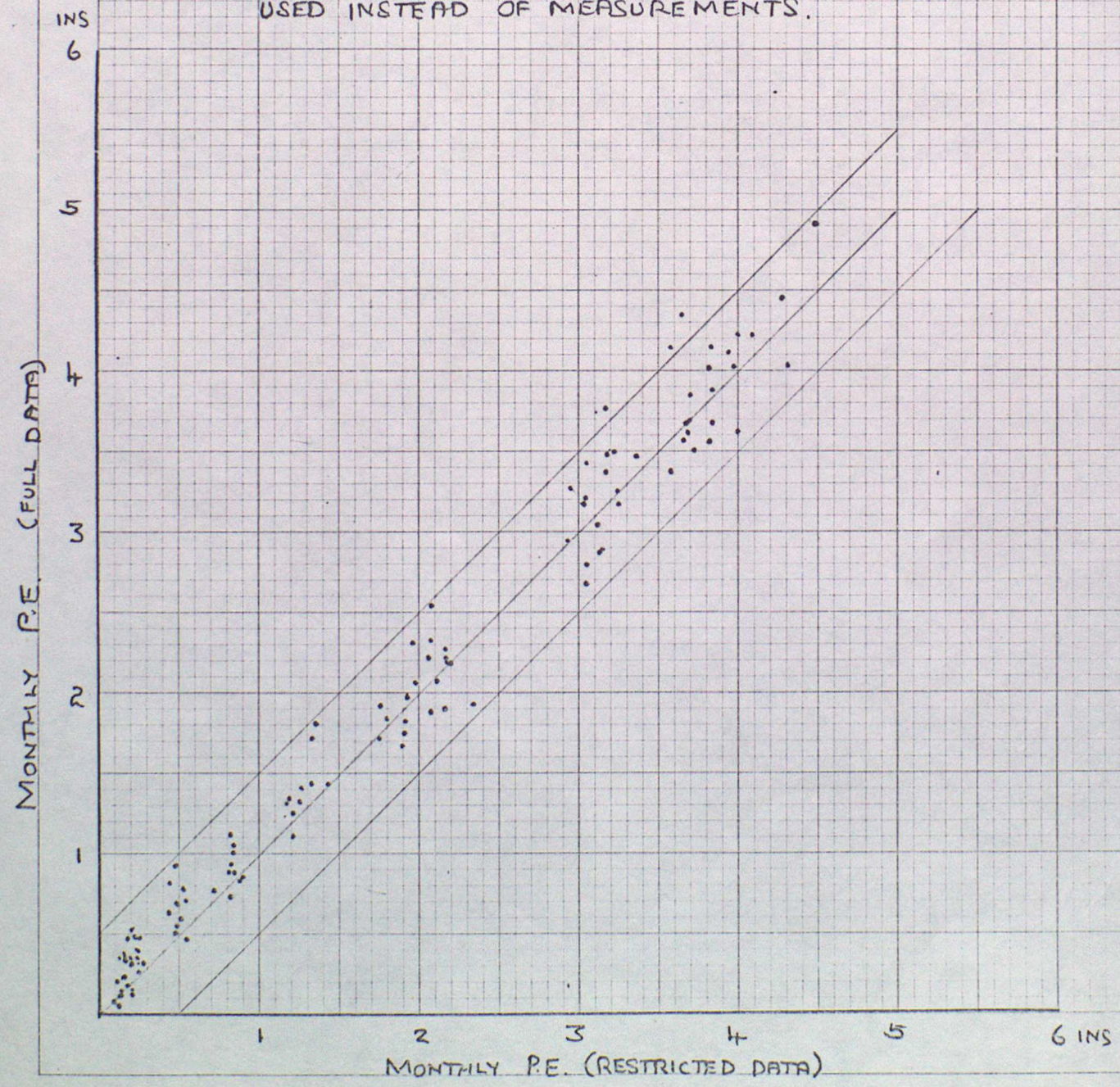


Fig. 4.

KEW 1961-70

ERRORS IN PENMAN P.E. (MONTHLY ESTIMATES) WHEN VAPOUR PRESSURE IS ESTIMATED FROM AVERAGE TEMPERATURE, DAILY DURATION OF BRIGHT SUNSHINE IS ESTIMATED FROM 1931-60 SUNSHINE AVERAGES AND AVERAGE TEMPERATURE AND MONTHLY AVERAGE WIND SPEEDS ARE USED INSTEAD OF MEASUREMENTS.



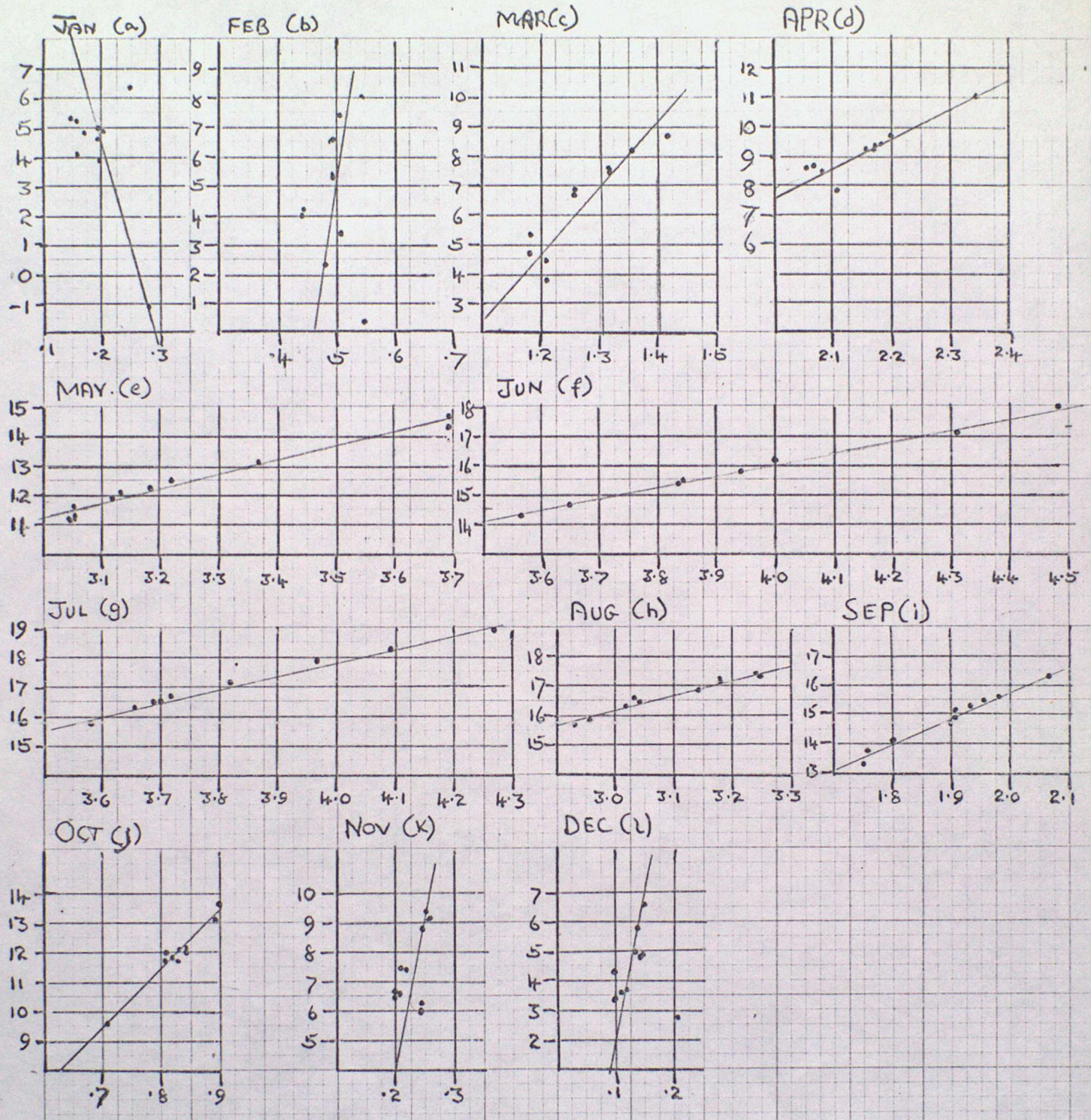


Fig.5. Monthly relationships between Average Screen Temperature and Modified (Penman) Potential Evaporation . Kew 1961-70.

TABLE 1.

ESTIMATION OF MONTHLY AVERAGE OF SUNSHINE DURATION AT KEW 1961-70

DISTRIBUTION OF ERRORS (IN HOURS) − = ESTIMATE LOW + = ESTIMATE HIGH.

(A) TEMPERATURE-BASED ESTIMATES (Fig. 1. (a) to (l)).

	−3·6 −4·0	−3·1 −3·5	−2·6 −3·0	−2·1 −2·5	−1·6 −2·0	−1·1 −1·5	−0·6 −1·0	−0·1 −0·5	0	+0·1 +0·5	+0·6 +1·0	+1·1 +1·5	+1·6 +2·0	+2·1 +2·5	+2·6 +3·0	+3·1 +3·5	+3·6 +4·0
JAN						1	2	5		2							
FEB				1	2	1		1	1	2			1		1		
MAR					1	1	1	1		5	1						
APR				1			1	3			1	2		1			1
MAY					1	1	3	1		1		1		1	1		
JUN		1	1					2		1	3			1	1		
JUL					1		3	2		4							
AUG						1	3			3	2	1					
SEP						1	1	1		3	1	2		1			
OCT					1		1	2		2	2	1		1			
NOV					1		2	2		3	2						
DEC					1		5	2		2							
YEAR		1	1	2	8	6	22	22	1	28	12	7	1	5	3		1
	←							62	1	57							→

(B) 1931-60 AVERAGES FOR KEW.

	−3·6 −4·0	−3·1 −3·5	−2·6 −3·0	−2·1 −2·5	−1·6 −2·0	−1·1 −1·5	−0·6 −1·0	−0·1 −0·5	0	+0·1 +0·5	+0·6 +1·0	+1·1 +1·5	+1·6 +2·0	+2·1 +2·5	+2·6 +3·0	+3·1 +3·5	+3·6 +4·0
JAN							3	2		5							
FEB					1		1	4	1	1		2					
MAR					2		2	1	1	2		2					
APR					1		1			1	4	1	1	1			
MAY						1	2	2		2	1	2					
JUN				1	2		1		1	2		2	1				
JUL						1	2	2		1		1	1	2			
AUG							1	2	1	2	1	2		1			
SEP			1				2	1		4	2						
OCT						2	3	1	1	1	2						
NOV						1		6	1	1	1						
DEC							2	4		3	1						
YEAR			1	1	6	5	20	25	6	25	12	12	3	4			
	←							58	6	56							→

(C) 1931-60 AVERAGES NOV–FEB, ½ (1931-60 AVERAGE + TEMP.-BASED EST.) OTHER MONTHS

	−3·6 −4·0	−3·1 −3·5	−2·6 −3·0	−2·1 −2·5	−1·6 −2·0	−1·1 −1·5	−0·6 −1·0	−0·1 −0·5	0	+0·1 +0·5	+0·6 +1·0	+1·1 +1·5	+1·6 +2·0	+2·1 +2·5	+2·6 +3·0	+3·1 +3·5	+3·6 +4·0
JAN							3	2		5							
FEB					1		1	4	1	1		2					
MAR							4	2		2	2						
APR					1		1			3	1	2		1	1		
MAY						1	2	1		2	3	1					
JUN				2			2	1		1	1	1	2				
JUL							4	2		1		3					
AUG							2	2		2	2	1	1				
SEP					1			3	1	1	2	2					
OCT							2	1	1	3		1	2				
NOV						1		6	1	1	1						
DEC							2	4		3	1						
YEAR				2	3	2	23	28	4	25	13	13	5	1	1		
	←							58	4	58							→

Table. 2

KEW 1957-1970 DISTRIBUTION OF MONTHLY TOTALS OF RUN OF WIND AT 2M

RUN =	61-70	71-80	81-90	91-100	101-110	111-120	121-130	131-140	141-150	151-160	161-170	171-180	MLS/DAY	Average	Max errors (1 Krs) (High)	Max errors (1 Krs) (Low)
JAN			1	2	3	1	X 2	2	1		2			121	−1.4	+1.7
FEB			1		2	2	2 X	4		2		1		127	−1.6	+1.9
MAR			1		1	4	2 X	2	2	1	1			126	−1.5	+1.3
APR				2		2	X 4	4	2					124	−1.1	+0.7
MAY			2	1	2	X 4	3	2						112	−1.1	+0.8
JUN			1	3	4 X	5	1							106	−0.6	+0.8
JUL			1	5	X 5	3								104	−0.5	+0.4
AUG			6	3 X	2	1	2							99	−0.6	+0.9
SEP			7	X 5	1	1								93	−0.3	+0.8
OCT	1	3	5 X	2	1	1		1						90	−0.8	+1.6
NOV	1	1	1	1	3 X	3	3	1						106	−1.4	+0.9
DEC		1	1	1	6	X	2	1	1	1				112	−1.4	+1.4

X shows "position" of average.

Table 3.

Penman Potential Evaporation at Kew 1961-70.

Wind measurements at 2m. above ground.

Measured daily duration of bright sunshine. Albedo 0.25.

Regression constants a = 0.18 b = 0.55.

Altitude 5 m = 15 feet above sea level.

Computer programme MESEA 10 (by.A.G.Seaton).

Values (estimates) are in inches.

Vapour pressures calculated in the normal manner.

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Averages
January ...	0·34	0·24	0·31	0·26	0·47	0·35	0·14	0·36	0·27	0·15	0·29
February ...	0·71	0·93	0·47	0·56	0·82	0·78	0·70	0·60	0·51	0·63	0·67
March ...	1·44	1·26	1·41	1·35	1·33	1·54	1·81	1·73	1·11	1·32	1·43
April ...	1·93	2·33	2·19	2·20	2·27	1·91	2·23	2·23	2·55	2·07	2·19
May ...	3·77	3·21	3·42	3·68	3·47	3·50	3·04	2·80	2·87	3·63	3·34
June ...	4·23	4·35	4·12	3·56	3·68	4·03	3·88	3·63	4·14	4·91	4·05
July ...	4·16	3·57	3·85	4·23	3·39	3·69	4·46	3·51	4·03	4·01	3·89
August ...	3·38	3·27	2·95	3·48	3·18	3·17	3·17	2·67	2·89	3·26	3·14
September	1·89	1·93	1·84	2·31	1·72	1·99	1·76	1·83	1·67	2·07	1·90
October ...	1·01	0·89	0·89	0·77	0·94	0·74	1·06	0·86	0·84	1·13	0·91
November	0·49	0·31	0·40	0·48	0·36	0·53	0·18	0·37	0·32	0·41	0·39
December	0·08	0·13	0·21	0·35	0·13	0·38	0·06	0·11	0·22	0·15	0·18
TOTAL ...	23·43	22·42	22·06	23·23	21·76	22·61	22·49	20·70	21·42	23·74	22·39

Table 4

Modified Penman Potential Evaporation at Kew 1961-70.

Details as in Table 2 except that:-

Wind values used were 1957-70 monthly averages.

Duration of bright sunshine and vapour pressure were estimated from temperature and 1931-60 sunshine averages.

Values (estimates) are in inches.

	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Averages
January ...	·17	·16	·28	·16	·19	·19	·15	·19	·25	·21	·19
February ...	·54	·49	·55	·49	·44	·51	·49	·61	·48	·44	·49
March ...	1·42	1·21	1·26	1·18	1·26	1·32	1·36	1·32	1·21	1·18	1·27
April ...	2·34	2·07	2·20	2·18	2·17	2·16	2·06	2·17	2·08	2·11	2·15
May ...	3·18	3·04	3·05	3·69	3·37	3·22	3·12	3·05	3·13	3·69	3·25
June ...	4·00	3·65	3·94	3·83	3·84	4·31	3·84	4·00	3·57	4·48	3·95
July ...	3·82	3·66	3·70	4·09	3·58	3·69	4·27	3·72	3·97	3·82	3·83
August ...	3·18	2·96	2·93	3·18	3·03	3·02	3·25	3·04	3·14	3·24	3·10
September	2·07	1·76	1·80	1·96	1·75	1·93	1·91	1·91	1·90	1·98	1·90
October ...	·84	·81	·83	·71	·83	·82	·84	·90	·89	·81	·83
November	·22	·20	·25	·24	·24	·20	·20	·21	·24	·26	·23
December	·10	·21	·11	·14	·14	·15	·13	·10	·12	·14	·13
TOTAL ...	21·88	20·22	20·90	21·85	20·84	21·52	21·62	21·12	20·98	22·36	21·32

Table 5

$\frac{1.025(PE')}{PE}$

Kew 1961-70

	Factor = 1/Average	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	Average
January ...	1·490	·513	·684	·925	·630	·444	·557	1·098	·541	·949	1·435	·671
February ...	1·335	·780	·540	1·199	·897	·550	·670	·717	·871	·965	·715	·749
March ...	1·099	1·011	·584	·916	·896	·971	·878	·770	·782	1·117	·916	·910
April ...	x	1·242	·910	1·030	1·016	·980	1·159	·947	·997	·836	1·044	1·007
May ...	x	·864	·971	·914	1·028	·995	·943	1·052	1·116	1·118	1·042	·997
June ...	x	·970	·860	·980	1·103	1·069	1·096	1·015	1·129	·883	·935	·999
July ...	x	·941	1·051	·985	·991	1·082	1·025	·981	1·087	1·010	·977	1·010
August ...	x	·965	·928	1·018	·937	·977	·977	1·051	1·167	1·114	1·019	1·012
September	x	1·122	·935	1·002	·869	1·042	·994	1·112	1·070	1·166	·981	1·025
October ...	1·069	·853	·933	·956	·945	·905	1·136	·812	1·073	1·085	·988	·935
November	1·653	·460	·661	·641	·513	1·684	·386	1·139	·581	·769	·650	·605
December	1·351	1·281	1·655	·537	·410	1·104	·405	2·221	·932	·559	·956	·740

Table 6. Tables for obtaining estimates of Modified (Penman) Potential Evaporation from Monthly Average Temperature. Kew Observatory. (Inches).

JAN. Fig.6 (a) values × 1·490

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
−2	·43	·43	·43	·44	·44	·44	·44	·44	·45	·45
−1	·41	·41	·41	·42	·42	·42	·42	·42	·43	·43
−0	·39	·39	·39	·40	·40	·40	·40	·40	·41	·41
0	·39	·39	·39	·38	·38	·38	·38	·38	·37	·37
1	·37	·37	·37	·36	·36	·36	·36	·36	·35	·35
2	·35	·35	·35	·34	·34	·34	·34	·34	·33	·33
3	·33	·33	·33	·32	·32	·32	·32	·32	·31	·31
4	·31	·31	·31	·30	·30	·30	·30	·30	·29	·29
5	·29	·29	·29	·28	·28	·28	·28	·28	·27	·27
6	·27	·27	·27	·26	·26	·26	·26	·26	·25	·25
7	·25	·25	·25	·24	·24	·24	·24	·24	·23	·23
8	·23	·23	·23	·22	·22	·22	·22	·22	·21	·21
9	·21	·21	·21	·20	·20	·20	·20	·20	·19	·19
10	·19	·19	·19	·18	·18	·18	·18	·18	·17	·17

FEB. Fig.6 (b) values × 1·335

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
−2	·60	·60	·60	·60	·60	·59	·59	·59	·59	·59
−1	·61	·61	·61	·61	·61	·60	·60	·60	·60	·60
−0	·62	·62	·62	·62	·62	·61	·61	·61	·61	·61
0	·62	·62	·62	·62	·62	·63	·63	·63	·63	·63
1	·63	·63	·63	·63	·63	·64	·64	·64	·64	·64
2	·64	·64	·64	·64	·64	·65	·65	·65	·65	·65
3	·65	·65	·65	·65	·65	·66	·66	·66	·66	·66
4	·66	·66	·66	·66	·66	·67	·67	·67	·67	·67
5	·67	·67	·67	·67	·67	·68	·68	·68	·68	·68
6	·68	·68	·68	·68	·68	·69	·69	·69	·69	·69
7	·69	·69	·69	·69	·69	·70	·70	·70	·70	·70
8	·70	·70	·70	·70	·70	·71	·71	·71	·71	·71
9	·71	·71	·71	·71	·71	·72	·72	·72	·72	·72
10	·72	·72	·72	·72	·72	·73	·73	·73	·73	·73

MAR Fig. 6 (c) values × 1·099

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
1	1·14	1·14	1·15	1·15	1·16	1·16	1·17	1·17	1·18	1·18
2	1·19	1·19	1·20	1·20	1·21	1·21	1·22	1·22	1·23	1·23
3	1·24	1·24	1·25	1·25	1·26	1·26	1·27	1·27	1·28	1·28
4	1·29	1·29	1·30	1·30	1·31	1·31	1·32	1·32	1·33	1·33
5	1·34	1·34	1·35	1·35	1·36	1·36	1·37	1·37	1·38	1·38
6	1·39	1·39	1·40	1·40	1·41	1·41	1·42	1·42	1·43	1·43
7	1·43	1·43	1·44	1·44	1·45	1·45	1·46	1·46	1·47	1·47
8	1·48	1·48	1·49	1·49	1·50	1·50	1·51	1·51	1·52	1·52
9	1·53	1·53	1·54	1·54	1·55	1·55	1·56	1·56	1·57	1·57
10	1·58	1·58	1·59	1·59	1·60	1·60	1·61	1·61	1·62	1·62
11	1·62	1·62	1·63	1·63	1·64	1·64	1·65	1·65	1·66	1·66
12	1·67	1·67	1·68	1·68	1·69	1·69	1·70	1·70	1·71	1·71

APR Fig. 6 (d) values.

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
6	1·84	1·85	1·86	1·87	1·88	1·89	1·90	1·91	1·92	1·93
7	1·94	1·95	1·96	1·97	1·98	1·99	2·00	2·01	2·02	2·03
8	2·04	2·05	2·06	2·07	2·08	2·09	2·10	2·11	2·12	2·13
9	2·14	2·15	2·16	2·17	2·18	2·19	2·20	2·21	2·22	2·23
10	2·24	2·25	2·26	2·27	2·28	2·29	2·30	2·31	2·32	2·33
11	2·34	2·35	2·36	2·37	2·38	2·39	2·40	2·41	2·42	2·43
12	2·44	2·45	2·46	2·47	2·48	2·49	2·50	2·51	2·52	2·53
13	2·54	2·55	2·56	2·57	2·58	2·59	2·60	2·61	2·62	2·63
14	2·64	2·65	2·66	2·67	2·68	2·69	2·70	2·71	2·72	2·73

MAY Fig. 6. (e) values.

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
9	2·55	2·57	2·59	2·61	2·63	2·65	2·67	2·69	2·71	2·73
10	2·75	2·77	2·79	2·81	2·83	2·85	2·87	2·89	2·91	2·93
11	2·95	2·97	2·99	3·01	3·03	3·05	3·07	3·09	3·11	3·13
12	3·15	3·17	3·19	3·21	3·23	3·25	3·27	3·29	3·31	3·33
13	3·35	3·37	3·39	3·41	3·43	3·45	3·47	3·49	3·51	3·53
14	3·56	3·58	3·60	3·62	3·64	3·66	3·68	3·70	3·72	3·74
15	3·76	3·78	3·80	3·82	3·84	3·86	3·88	3·90	3·92	3·94
16	3·96	3·98	4·00	4·02	4·04	4·06	4·08	4·10	4·12	4·14

JUN Fig. 6 (f) values.

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
12	2·97	3·00	3·02	3·05	3·07	3·09	3·12	3·14	3·17	3·19
13	3·22	3·25	3·27	3·30	3·32	3·34	3·37	3·39	3·42	3·45
14	3·48	3·51	3·53	3·56	3·58	3·60	3·63	3·65	3·67	3·70
15	3·73	3·75	3·77	3·80	3·82	3·85	3·88	3·90	3·93	3·96
16	3·99	4·02	4·04	4·07	4·09	4·11	4·14	4·16	4·19	4·21
17	4·24	4·27	4·29	4·32	4·34	4·36	4·39	4·41	4·44	4·47
18	4·50	4·53	4·55	4·58	4·60	4·62	4·65	4·67	4·70	4·72
19	4·75	4·78	4·80	4·83	4·85	4·87	4·90	4·92	4·95	4·98
20	5·01	5·04	5·06	5·09	5·11	5·13	5·16	5·18	5·21	5·24

JUL Fig. 6 (g) values.

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
13	2·94	2·97	2·99	3·01	3·03	3·05	3·08	3·10	3·12	3·14
14	3·16	3·19	3·21	3·23	3·25	3·27	3·30	3·32	3·34	3·36
15	3·38	3·41	3·43	3·45	3·47	3·49	3·52	3·54	3·56	3·58
16	3·60	3·63	3·65	3·67	3·69	3·71	3·73	3·76	3·78	3·80
17	3·82	3·85	3·87	3·89	3·91	3·93	3·95	3·98	4·00	4·02
18	4·04	4·07	4·09	4·11	4·13	4·15	4·17	4·20	4·22	4·24
19	4·26	4·29	4·31	4·33	4·35	4·37	4·39	4·42	4·44	4·46
20	4·48	4·51	4·53	4·55	4·57	4·59	4·61	4·64	4·66	4·68
21	4·70	4·73	4·75	4·77	4·79	4·81	4·83	4·86	4·88	4·90
22	4·92	4·95	4·97	4·99	5·01	5·03	5·05	5·08	5·10	5·12

AUG Fig. 6 (h) values.

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
14	2·54	2·56	2·58	2·60	2·62	2·64	2·66	2·69	2·71	2·73
15	2·75	2·77	2·79	2·81	2·83	2·85	2·87	2·90	2·92	2·94
16	2·96	2·98	3·00	3·02	3·04	3·06	3·08	3·10	3·13	3·15
17	3·17	3·19	3·21	3·23	3·25	3·27	3·29	3·31	3·34	3·36
18	3·38	3·40	3·42	3·44	3·46	3·48	3·50	3·52	3·55	3·57
19	3·59	3·61	3·63	3·65	3·67	3·69	3·71	3·73	3·76	3·78
20	3·80	3·82	3·84	3·86	3·88	3·90	3·92	3·94	3·97	3·99

SEP Fig. 6 (i) values

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
10	1·34	1·35	1·37	1·38	1·39	1·40	1·41	1·43	1·44	1·45
11	1·46	1·47	1·49	1·50	1·51	1·52	1·53	1·54	1·55	1·56
12	1·57	1·58	1·60	1·61	1·62	1·63	1·64	1·66	1·67	1·68
13	1·69	1·70	1·72	1·73	1·74	1·75	1·76	1·77	1·78	1·79
14	1·80	1·81	1·83	1·84	1·85	1·86	1·87	1·89	1·90	1·91
15	1·92	1·93	1·95	1·96	1·97	1·98	1·99	2·00	2·01	2·02
16	2·03	2·04	2·06	2·07	2·08	2·09	2·10	2·11	2·13	2·14
17	2·15	2·16	2·18	2·19	2·20	2·21	2·22	2·23	2·24	2·25
18	2·26	2·27	2·29	2·30	2·31	2·32	2·33	2·35	2·36	2·37

OCT. Fig. 6 (j) values X 1·069

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
6	·56	·56	·57	·57	·58	·58	·59	·59	·60	·60
7	·61	·61	·62	·62	·63	·63	·64	·65	·66	·66
8	·67	·67	·68	·68	·69	·69	·70	·70	·71	·71
9	·72	·72	·73	·73	·74	·74	·75	·75	·76	·76
10	·77	·77	·78	·78	·79	·79	·80	81	·82	·82
11	·83	·83	·84	·84	·85	·85	·86	·86	·87	·87
12	·88	·88	·89	·89	·90	·90	·91	·91	·92	·92
13	·93	·93	·94	·94	·95	·95	·96	·97	·97	·98
14	·99	·99	1·00	1·00	1·01	1·01	1·02	1·02	1·03	1·03
15	1·04	1·04	1·05	1·05	1·06	1·06	1·07	1·07	1·08	1·08
16	1·09	1·09	1·10	1·10	1·11	1·11	1·12	1·12	1·13	1·13

NOV Fig. 6 (k) values X 1·653

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
3	·32	·32	·32	·32	·32	·32	·32	·32	·32	·32
4	·33	·33	·33	·33	·34	·34	·34	·34	·34	·34
5	·35	·35	·35	·35	·36	·36	·36	·36	·36	·36
6	·37	·37	·37	·37	·37	·37	·37	·37	·37	·37
7	·38	·38	·38	·38	·38	·39	·39	·39	·39	·39
8	·40	·40	·40	·40	·40	·40	·40	·40	·40	·40
9	·41	·41	·41	·41	·41	·42	·42	·42	·42	·42
10	·43	·43	·43	·43	·43	·44	·44	·44	·44	·44
11	·45	·45	·45	·45	·45	·45	·45	·45	·45	·45
12	·46	·46	·46	·46	·46	·46	·46	·46	·46	·46

DEC. Fig. 6 (2) values X 1·351

T°C	0	·1	·2	·3	·4	·5	·6	·7	·8	·9
-2	·06	·06	·06	·06	·06	·06	·05	·05	·05	·05
-1	·07	·07	·07	·07	·07	·07	·06	·06	·06	·06
-0	·09	·09	·09	·09	·09	·08	·08	·08	·08	·08
0	·10	·10	·10	·10	·10	·11	·11	·11	·11	·11
1	·12	·12	·12	·12	·12	·12	·12	·12	·12	·12
2	·13	·13	·13	·13	·13	·14	·14	·14	·14	·14
3	·15	·15	·15	·15	·15	·15	·15	·15	·15	·15
4	·16	·16	·16	·16	·16	·16	·17	·17	·17	·17
5	·18	·18	·18	·18	·18	·18	·18	·18	·18	·18
6	·19	·19	·19	·19	·19	·19	·19	·19	·19	·19
7	·20	·20	·20	·20	·20	·20	·21	·21	·21	·21
8	·22	·22	·22	·22	·22	·22	·22	·22	·22	·22